Pressure Distribution in Fluids

INTRODUCTION

Fluids are generally found in contact with surfaces. Water in the sea and in reservoirs are in contact with the ground and supporting walls. Atmospheric air is in contact with the ground. Fluids filling vessels are in contact with the walls of the vessels. **Fluids in contact with surfaces exert a force on the surfaces**. The force is mainly due to the specific weight of the fluid in the case of liquids. In the case of gases molecular activity is the main cause of force exerted on the surfaces of the containers. Gas column will also exert a force on the base, but this is usually small in magnitude. **When the whole mass of a fluid held in a container is accelerated or decelerated without relative motion between layers inertia forces also exert a force on the container walls**. This alters the force distribution at stationary or atatic conditions. Surfaces may also be immersed in fluids. A ship floating in sea is an example. In this case the force exerted by the fluid is called buoyant force. This is dealt with in a subsequent chapter. The force exerted by fluids vary with location. The variation of force under static or dynamic condition is discussed in this chapter. This chapter also deals with pressure exerted by fluids due to the weight and due to the acceleration/deceleration of the whole mass of the fluid without relative motion within the fluid. Liquids held in containers may or may not fill the container completely. When liquids partially fill a container a free surface will be formed. Gases and vapours always expand and fill the container completely.

PRESSURE

Pressure is a measure of force distribution over any surface associated with the force. Pressure is a surface phenomenon and it can be physically visualised or calculated only if the surface over which it acts is specified. Pressure may be defined as the force acting along the normal direction on unit area of the surface. However a more precise definition of pressure,
P is as below:

$$\mathbf{P = \lim_{A\text{-}a} (\Delta F/\Delta A) = dF/dA}$$

F is the resultant force acting normal to the surface area A. ‘a’ is the limiting area which will give results independent of the area. This explicitly means that pressure is the ratio of the elemental force to the elemental area normal to it. The force dF in the normal direction on the elemental area dA due to the pressure P is

$$dF = P\,dA$$

The unit of pressure in the SI system is N/m^2 also called Pascal (Pa). As themagnitude is small kN/m^2 (kPa) and MN/m^2 (Mpa) are more popularly used. The atmospheric pressure is approximately 105 N/m^2 and is designated as ‘‘bar’’. This is also a popular unit of pressure. In the metric system the popular unit of pressure is kgf/cm^2. This is approximately equal to the atmospheric pressure or 1 bar.
The pressure measured by the gauge is called gauge pressure. The sum of the gauge pressure and the outside pressure gives the absolute pressure which actually is the pressure measured.

Absolute pressure = gauge pressure + surrounding pressure

PASCAL’S LAW

In fluids under static conditions pressure is found to be independent of the orientation of the area. This concept is explained by Pascal’s law which states that the pressure at a point in a fluid at rest is equal in magnitude in all directions. Tangential stress cannot exist if a fluid is to be at rest. This is possible only if the pressure at a point in a fluid at rest is the same in all directions so that the resultant force at that point will be zero.
Hence, the pressure at any point in a fluid at rest is the same in all directions. The pressure at a point has only one value regardless of the orientation of the area on which it is measured. This can be extended to conditions where fluid as a whole (like a rotating container) is accelerated like in forced vortex or a tank of water getting accelerated without relative motion between layers of fluid. Surfaces generally experience compressive forces due to the action of fluid pressure.